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CORRUGATED BOARD AND ITS COMPONENTS

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1. Introduction

One of the greatest revolutions in the domain of packaging occurred just before the first world war. At that time, board and corrugated board in particular made its mark on the packaging market of the U. S. A. as a really good material for transport purposes in keen competition with wooden forms of packing which had earlier almost exclusively dominated the scene.

In order to achieve this result, the manufacturers of corrugated board had, by means of extensive scientific and statistical investigations, to assure the military and civil authorities, and equally the important railway companies, that the new packaging material provided protection which was at least equal to, and in many instances an even better form of protection than a wood-encased package for an object packed in it. The qualities demanded, and the standards which were then drawn up for corrugated board and packages made of corrugated board, have served as a basis for Rule 41 in the U. S. Uniform Freight Classification which has in its turn functioned as a model in nearly all other countries for the formulation of the corresponding standards and regulations for transport packages.

2. History of corrugated board

Corrugated packaging material was taken into use for the first time in 1871, when the American Albert L. Jones was granted a patent in U. S. A. covering a product which according to the description lodged could be utilized for the packaging of bottles and similar items. This product was made of board, cardboard or other suitable material, and conformed to the quality today known as "corrugated medium". that is to say the corrugated component of corrugated board. This

packaging material patented by Jones had the inconvenience that it was easily stretched and became flat in use, and at the same time lost its elasticity. A patent of 1874 was concerned with an improvement to the new packaging material by sizing a flat paper or board on one or both sides of the "corrugated medium". This packaging material, which corresponds to modern corrugated board, was for a long time used as a wrapper and for the inside lining of wooden containers as well as for cell partitions and protective dividing walls. The production of shipping containers of corrugated board was not initiated until 1894, and from this date it could be stated that corrugated board had really begun its victorious advance as a packaging material.

3. Qualities of corrugated board

The original corrugated paper, "corrugated medium", has with time been developed into the following different types of corrugated board:

a. Single Lined (-Faced) Corrugated Board
with one flat and one corrugated layer

b. Double Lined (-Faced) Corrugated Board
with two flat layers (liners), and one corrugated layer between the liners

c. Double Wall Corrugated Board
with three flat layers and two corrugated layers

d. Triple Wall Corrugated Board
with four flat layers and three corrugated layers.

The flat board layers are usually referred to as liners, such as "testliner" or "kraftliner", and in its turn the material for the corrugated layer is known as "fluting board" or merely "fluting", and at times also "ninepoint" board.

Corrugated board can also be classified into different groups based upon the shape and size of the corrugated waves.

Fortunately, it has proved possible to keep the number of different wave shapes within reasonable limits. Corrugated board is nowadays usually divided into three groups:

	In Europe		In America	
	wave height	wave length	wave heigt	waves per foot
Coarse wave: A-flute	4.8 - 5.5 mm	8.0 - 9.5 mm	3/16"(4.76 mm)	35-37
Fine wave B-flute	3.0 - 3.5 mm	4.5 - 6.2 mm	1/10-1/8" (2.54-3.17 mm)	50-52

	In Europe		In America	
	wave height	wave length	wave height	wave per foot
Middle wave C-flute	3.5-4.5 mm	6.3-7.9 mm	5/32" (3.97 mm)	41-45

"Wave length" refers to the distance between two successive wave peaks.

Recently, there has also appeared an unusual coarse wave type, with a height of about 8 mm and a wave length of over 10 mm. The wave shape varies somewhat, depending upon the manufacturing company, but nevertheless it is possible to distinguish between two main types: one resembling a sine curve, and another with a more pronounced V-shape. Wear of the corrugating rolls, and the milling of worn-out rolls involve that wave shapes are encounted which differ from the main types described above as regards both shape and dimensions.

Generally, the wave is straight; a more snakily sinous wave type is produced only exceptionally.

4. Fluting board

The demands for quality imposed on the board for corrugated medium or fluting were earlier rather modest. Nearly every board quality was suitable for this purpose. Waste paper, knot cellulose, and straw pulp constituted the raw materials for fluting, and the strength properties were regulated through variation of the basis weight. The result was that the basis weight was mostly kept between 180-230 g/sq. m but the strength properties were rather low.

The day-by-day increase in the intensity of competition, the more exacting demands for the strength of transport packages and especially for export containers, coupled with the higher speed of the corrugators have compelled producers to provide new fluting qualities with properties of strength which are in closer conformity with actual requirements.

It is important that fluting board can be corrugated easily and that it also preserves the corrugation. In addition, it should have good sizing properties, be sufficiently rigid, and possess good elasticity in its corrugated state. It is advantageous that the tensile strength, stretch and tear strength are high, whereas the Mullen bursting strength is not so important.

Packaging research has demonstrated that high values for the properties of compression strength and stiffness result in the most satisfactory corrugated-board containers. For this reason, semi-chemical birch pulps have been

the main raw material for fluting board. Semi-chemical fluting board is preferably manufactured in only two basic weights, 112 and 127 g/sq. m. Nevertheless, a quality of 85 g/sq. m is sometimes produced. The values obtained by the Concora Medium Test, CMT, are mostly utilized for the appraisal of different fluting qualities. In general, Finnish semi-chemical fluting board has the following CMT-values:

basis weight, g/sq. m	CMT, lbs
85	ca 40
112	" 60-70
127	" 80-90

Some of the manufacturers of corrugated board consider that a very high value for CMT can cause broken waves, or sizing difficulties. In many cases this, however, only depends on a suitable pretreatment of fluting board, and on an unsufficient knowledge of the sizing properties. Wastepaper, straw, especially wheat straw, bagasse, knot-pulps, etc. are still used extensively as raw materials for fluting board, both alone and in mixtures. Of course, it then becomes necessary to increase the basis weight up to 180 - 230 g/sq. m, and to strike a balance as regards the CMT-values. Large-scale investigations have been engaged in with the aim of improving these properties of fluting board by means of special pulp sizing methods, or by the addition of vegetable slime or synthetic resins, but nevertheless no satisfactory results have been achieved, either with respect to economy or quality.

Semi-chemical pulps for fluting board can be prepared by different methods and from various kinds of wood. However, the best result is obtained by cooking hardwood pulps according to the NSSC method.

5. Linerboard

The liner layer of corrugated board gives many important properties to the corrugated board, and thus the quality of liner board is of considerable significance. In the first place, the liner layer should withstand most of the handling, transport, conditions of climate, etc. to which it is subjected and still possess good sizing, creasing, and printing properties. Thus, a great deal of work has been necessary in order to obtain the best possible qualities of liner for corrugated board. In Europe, the most satisfactory results have been achieved with kraftliner, testliner and kraftpaper. Apart from these qualities, also a large number of other qualities are utilized, depending upon the intended employment of the final corrugated board.

The basis weight of liner board varies within limits, usually between 90-450 g/sq. m, based upon the composition of the pulp and the strength required.

Kraft paper is a tough and strong material which is used extensively, but nowadays it is being more and more pushed aside by the cheaper kraftliner, which is usually produced in large, fast board machines with double headboxes. Testliner is a board of duplex-character with a top layer of bleached or unbleached cellulose, and a body consisting of cheaper pulps such as mechanical pulp, knotpulp, waste paper, etc. It is less expensive than kraftpaper and kraftliner, but it is not so strong. Recently, the addition of up to 50 per cent of short-fibred hardwood pulps to the surface layer of the liner board has provided satisfactory results.

The strength properties of liner board depend on the basic weight, and for this reason there is sought a board quality with a low basic weight and high strength values. Kraftliner occupies a favourable position in this respect. The following values can be reported with regard to the bursting strength of Finnish kraftliner qualities:

basis weight, g/sq. m	Mullen, kg/sq. cm
130	6.3 - 7.0
150	7.0 - 8.0
180	8.0 - 9.5
300	9.5 -10.5

The tensile strength value is high: in the machine direction it is 6000 - 10500 m, and in the cross direction 2.700 - 4.000 m, the respective stretch values being 1.1 - 2.1 % and 2.5 - 5.2 %.

Modern advertising and the supermarkets have observed that the sides of shipping containers are very suitable for publicity purposes, and for this reason nearly all such packages are printed with illustrations and text. This demands a good printing surface, and thus today liner board is to an ever-increasing extent bleached or is provided with a top layer which is completely coloured. However, these methods do not always prove satisfactory, and the coated qualities of linerboard are continuously gaining more footing.

Transport packages should also resist humidity to a major or minor degree, and for this reason linerboard may be waxed, sized with special glues, or with plastic treated. In many cases, the board has to be impregnated against attack by insects or rodents. Packages for tropical transports involve the use of linerboard which is prepared with chemicals, such as phenolates and mercury preparates to resist the formation of mould and fungi.

6. Adhesives

One of the most important components in the manufacture of corrugated board is the adhesive. Generally speaking, the adhesive utilized for fixing the corru-

gated fluting paper to the liner layer is composed of waterglass or starch, and recently certain synthetic resins also.

Waterglass is an adhesive of mineral origin, silicate of sodium, with a composition which varies. If a good sizing effect and a suitable sizing speed are to be obtained, the relation between the amounts of Na_2O and SiO_2 included in the adhesive have to be prescribed; usually there is 8 - 10 per cent of Na_2O and 28 - 30 per cent of SiO_2. The concentration of waterglass varies slightly, but usually it is about 30-40 per cent.

The one-time lower price of waterglass made it the adhesive most generally employed for the preparation of corrugated board, even if it possesses some unfavourable characteristics. It hardens like crystal, and makes the corrugated board rather firm and rigid. Waterglass easily sticks to machine parts of metal, which means that a corrugator must be frequently cleaned; this is a rather troublesome operation. The hardness of waterglass soon blunts the cutting edges, and for the same reason the corrugating rolls are subjected to considerable wear.

Waterglass is fairly sensitive to humidity; this means that the sized seams can be dissolved in a humid state, and the corrugated board will peel. During the subsequent drying period, waterglass will no longer stick the layers together, as happens in a corrugated board sized with starch.

In wet weather, in humid store-places, in tropical countries, and particularly also at low temperatures under humid conditions the sized seams will weaken appreciably during a relatively short period.

The high alkalinity of water glass (pH about 10-11) entails that in certain cases the ability of the liner layer to take size can be affected. Moreover, the colour of the liner board may be changed in such way that there may occur "zebra streaks", especially if the liner layer is made of virgin fibres. If the liner has been produced from waste paper the streak formation is minimal, or does not exist at all. If the corrugated board is printed with alkali-sensitive inks, waterglass can completely destroy the print. The effect of alkalinity is observed most clearly at high relative humidities.

Double corrugated board sized with waterglass needs about 25-30 per cent more adhesive than corrugated board sized with starch. Further to this, the sizing speed for corrugated board sized with waterglass is appreciably lower.

The manufacturers of waterglass have engaged in a great deal of work for the improvement of the properties of waterglass to ensure that they can meet the

keen competition of the manufacturers of starch adhesives.

The use of starch as an adhesive in the preparation of corrugated board originate in the U.S.A., where starch adhesives have almost entirely eliminated waterglass adhesives.

Starch needs a higher sizing temperature, and also en efficient mixing and preparation plant. The storage time for the ready made starch is rather short, often amounting to not more than 2-3 days.

Starch adhesives can easily be removed from the machine rolls and other metal parts of the corrugator. Starch causes no "zebra streaks", and as it is nearly neutral, neither does there occur any discoloration. Starch does not injure packed goods.

Usually, starch adhesive contains about 21-22 per cent starch, together with some additives, such as soda and borax, ingredients which adjust the gelatination temperature and the viscosity.

Starch adhesives with good wet strength properties can be obtained by adding certain chemicals and resins such as ureformaldehyde, melaminformaldehyde, aluminum sulphate, and recently resorcinol resins also. At the moment, the starch manufacturers are working energetically to improve their products in this respect. The starch quality which gives the best results is prepared from corn.

Corrugated board sized with starch does not possess such satisfactory stiffness as corrugated board sized with waterglass, and some consumers consider this to be a great disadvantage in the production of corrugated containers. Corrugated board sized with starch is a suitable packaging material for tropical conditions and for other extreme conditions of climate as a consequence of its good wet strength and low hygroscopicity.

The continuously increasing demands imposed on corrugated board and the fastmoving corrugators, the speed of which is constantly rising, have brought in their train new adhesives based upon synthetic resins. Good results have been obtained with polyvinyl-acetate. Large-scale experiments with many different qualities of synthetic resins have been carried out, and this testing work is still in progress, especially in the U.S.A. One of the most important aims is that of producing, if possible, a cold-jointing adhesive, which would provide an opportunity to eliminate the long drying section in the corrugated board machine.

7. Conclusion

Increasing mechanization and automation in the handling of goods, the greatly intensified exchange of commodities and foodstuffs, expanding international trade, the development of speedy transportation vehicles, along with many other factors, have led to the immense progress and distribution of packages made of corrugated board. As a country develops, the greater become its demands for efficient, light, and inexpensive means of packaging. Corrugated board has become an ideal packing material, and shows every possibility of being converted into still better qualities, and of becoming even more popular and widely used.

Unfortunately, it is a very difficult matter to obtain statistics on the actual consumption of corrugated board in different countries, and to find a comparable index which could indicate the consumption per capita in these countries. The vital organisation, Fédération Européenne des Fabricants de Carton Ondulé, F.E.F.C.O. has provided the following information on the consumption per annum and per capita in 1960:

USA	43.8 kg	Switzerland	8.4 kg
Sweden	14.4 "	Italy	6.8 "
Holland	14.7 "	Belgium	5.9 "
Germany	10.2 "	Norway	5.9 "
England	10.1 "	Austria	2.6 "
France	10.1 "	Spain	0.7 "

Harry J. Bettendorf has carried out a large-scale investigation of the production of corrugated board; he arrived at the following results reported in sq. ft. per capita in 1960:

Egypt	6.4	Italy	117.4
Greece	7.1	Denmark	127.5
Portugal	11.0	Switzerland	144.2
Spain	13.2	France	144.5
Austria	45.9	United Kingdom	175.5
Finland	104.3	Western Germany	208.2
Belgium	104.9	Sweden	283.9
Norway	113.9	USA	593.8
Israel	114.8		

This list is by no means complete; the Eastern States and the development countries are not included.

The development countries, for which there has been planned an efficient utilization of natural and industrial products, will soon in many respects need suitable packaging material for the home market and for export. In these countries, corrugated board will also be the most important packaging material. The rise in demand will certainly result in the importation of packaging materials or the initiation of home production. Unfortunately, the transportation of corrugated

board or of containers of corrugated board cannot be recommended except in special cases, particularly as regards remote countries, as in view of the space required for corrugated board its transportation will be un economic; for corrugated board, the space required is about 3-6 times as much as for linerboard and fluting.

The development countries, usually situated far from the countries actually producing corrugated board in Europe and in America, will increase their needs and demands for an efficient packaging material for their consumption products and export goods. The construction of corrugated board mills, complete with container plants, in consumption or export centres, or nearby, soon enters one's mind, and this is also rather easy to realise. Modern corrugating machines are efficient and versatile, with a speed of over 200 m/min. The staff need not be large in number and the plants are easy to set up and to maintain.

The raw material, fluting, liner and adhesive can, at least initially, be obtained from those countries which over-produce. Later on, opportunities will arise for the manufacture of fluting board and liner-board from the raw materials of each country, from bagasse, straw, hard- and softwoods, but this will constitute a larger scale economic project and will require in addition well-trained foremen and skilled workers.

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